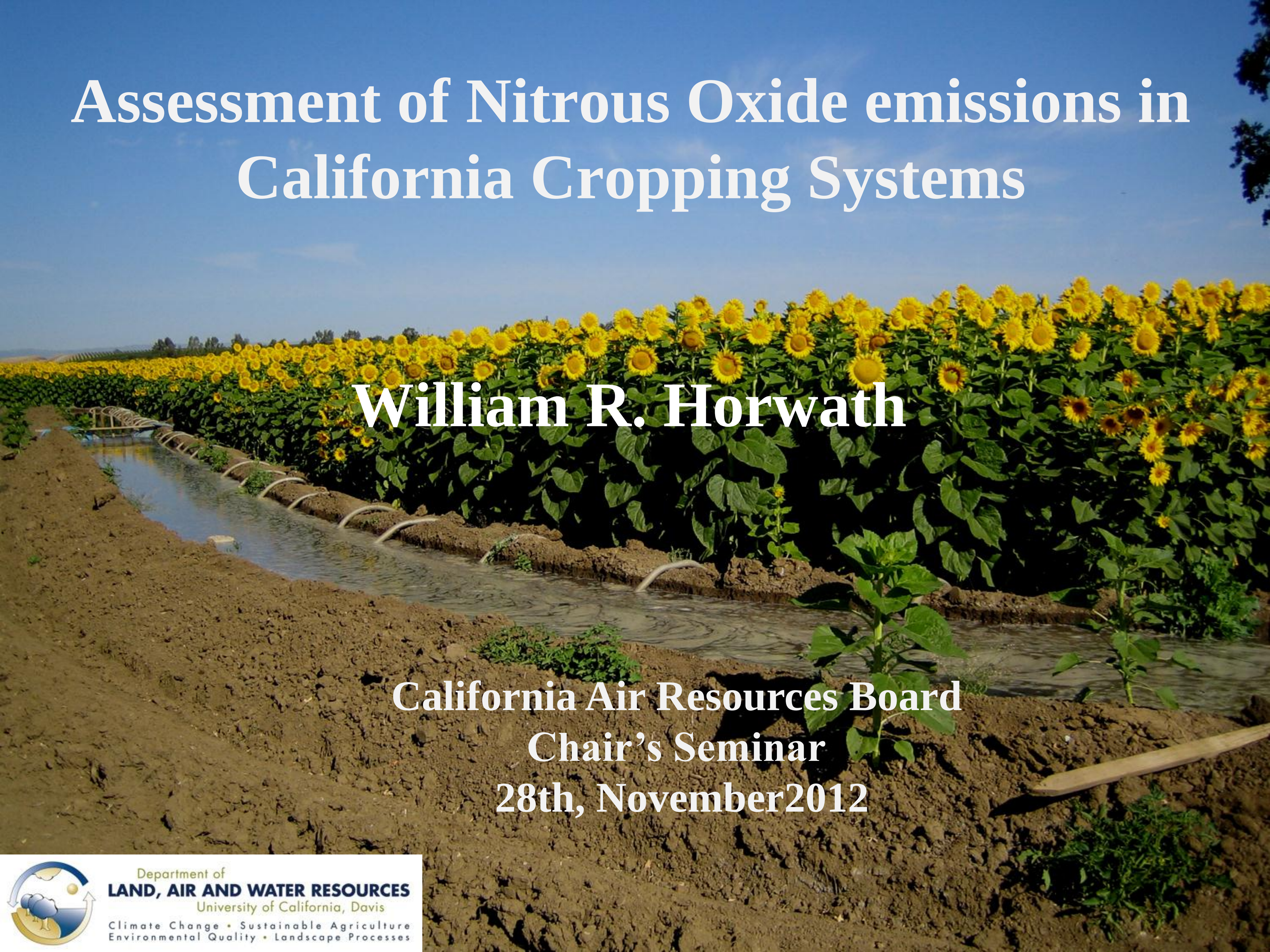

Assessment of Nitrous Oxide emissions in California Cropping Systems

William R. Horwath

California Air Resources Board
Chair's Seminar
28th, November2012

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In this talk

- **California's Climate Change Act AB 32**
  - **Background on N_2O emissions**
- **CARB and CalRecycle projects**
  - **ASSESSMENT OF BASELINE NITROUS OXIDE EMISSIONS IN CA CROPPING SYSTEM (Completed)**
  - **RESEARCH TO EVALUATE NITROUS OXIDE EMISSIONS FROM COMPOST IN SUPPORT OF AB 32 SCOPING PLAN COMPOSTING MEASURE (Ongoing)**
- **Perspective/conclusions**

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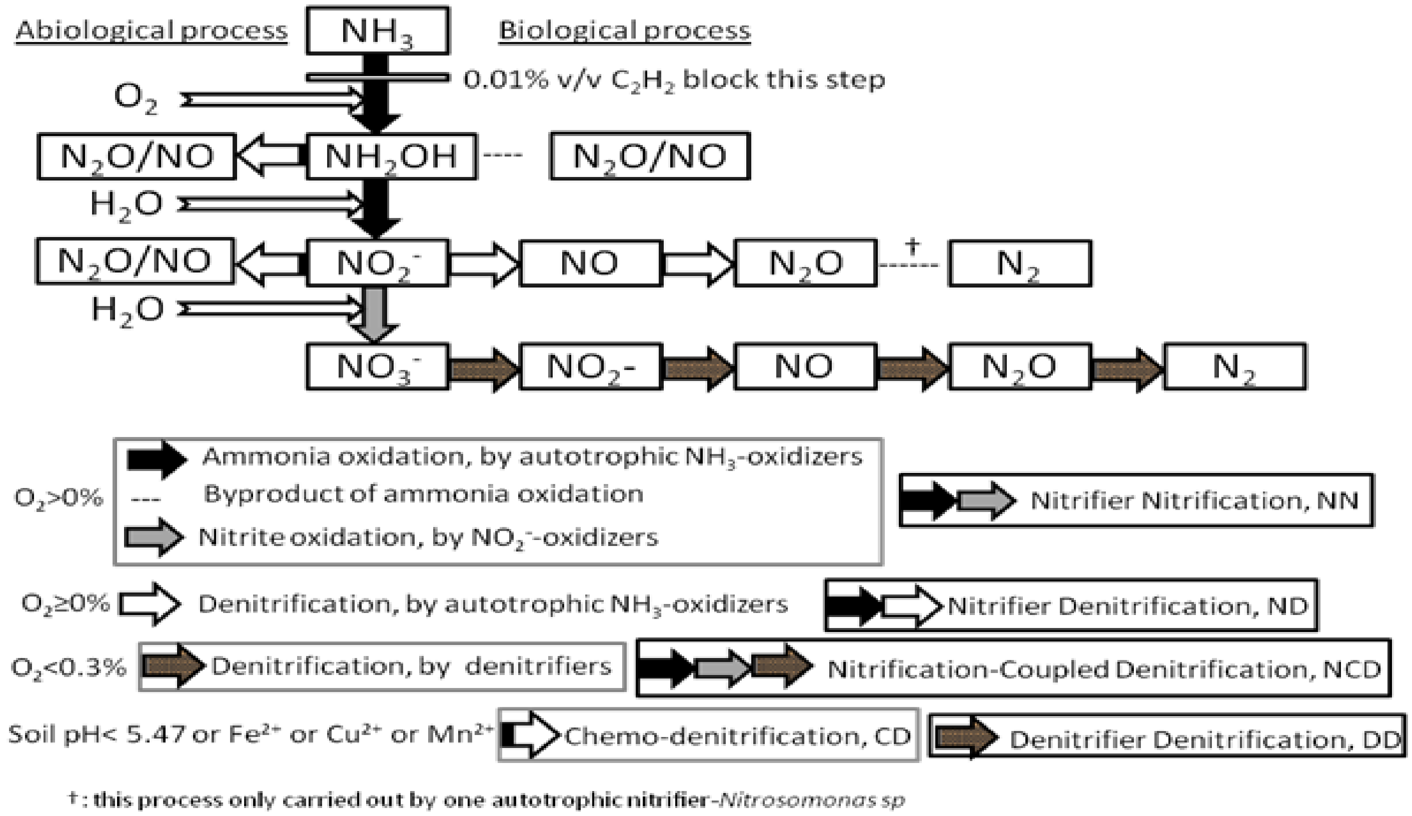
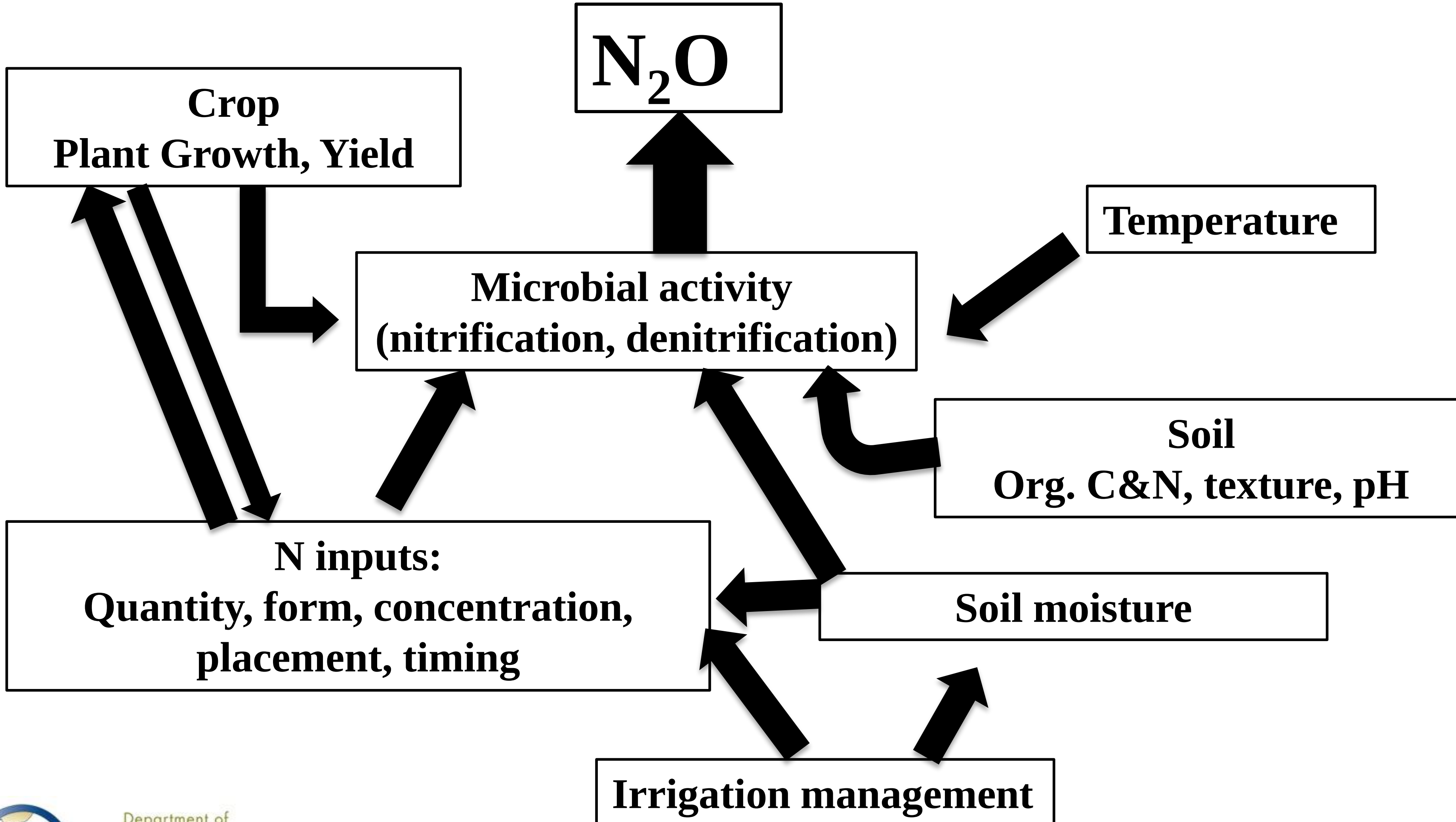
Objectives

- **Achieve goals of AB32 (Global Warming Solutions Act):**
  - **CA agricultural land: 52% of total N_2O (ARB 2010)**
  - **4% of CA total GHG emissions (CEC, 2005)**
- **Baseline N_2O emissions**
- **Emission factors**
- **Data for model calibration and validation**
- **Best management practices and mitigation potential**

Pathways for N_2O emission



Controls on N_2O Emissions from Agricultural Soil



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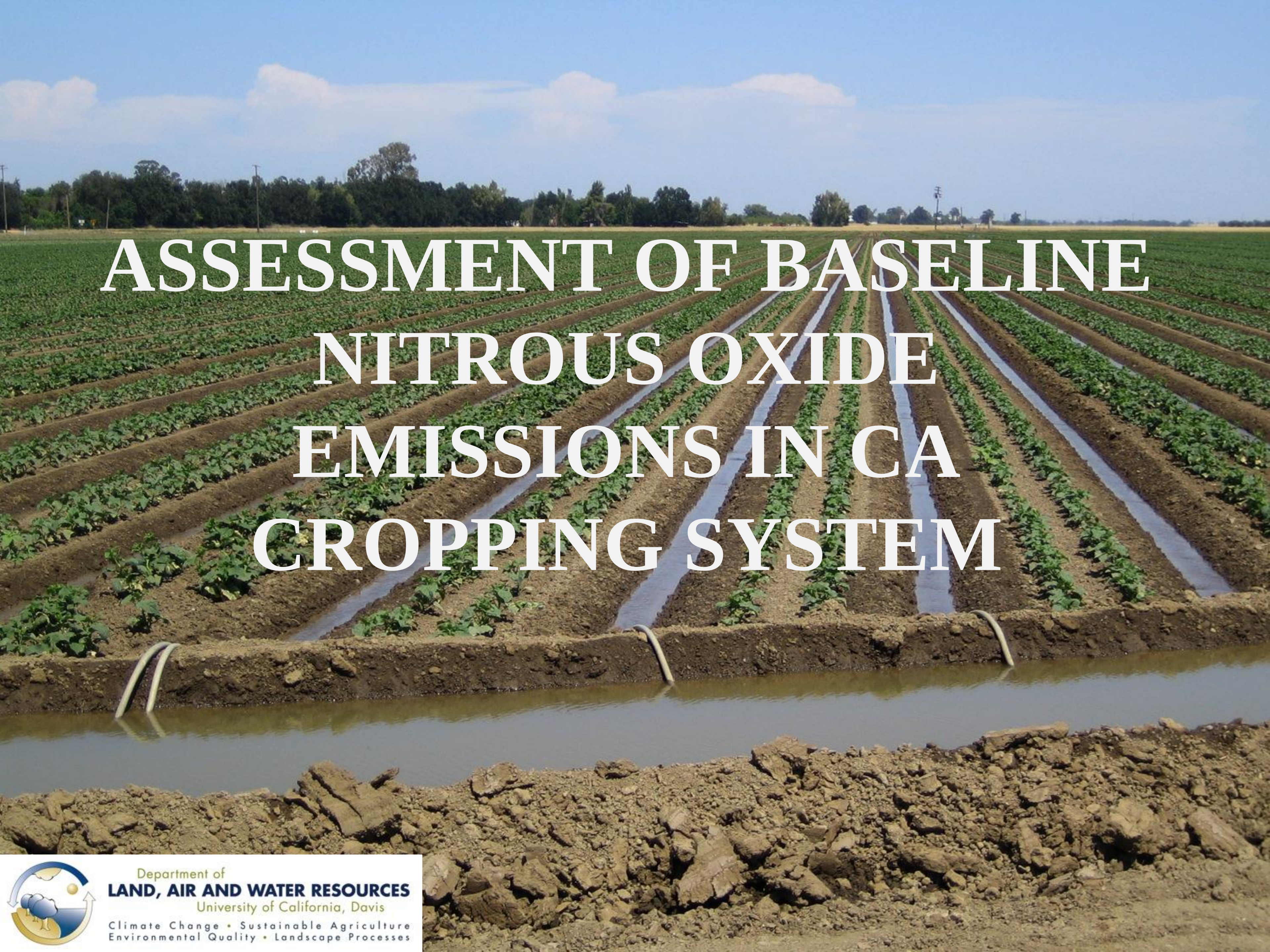
ASSESSMENT OF BASELINE NITROUS OXIDE EMISSIONS IN CA CROPPING SYSTEM



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Baseline N_2O Emissions in CA Cropping Systems

- Tomato, lettuce, wheat, alfalfa
- Emphasis on N fertilizer rates
- Relationships among N_2O emissions, yields, crop N use efficiency (crop N uptake and N removal)
- 2-year trials to determine annual N_2O emissions and emission factors

Methodology: Chambers for N_2O flux measurements in the field

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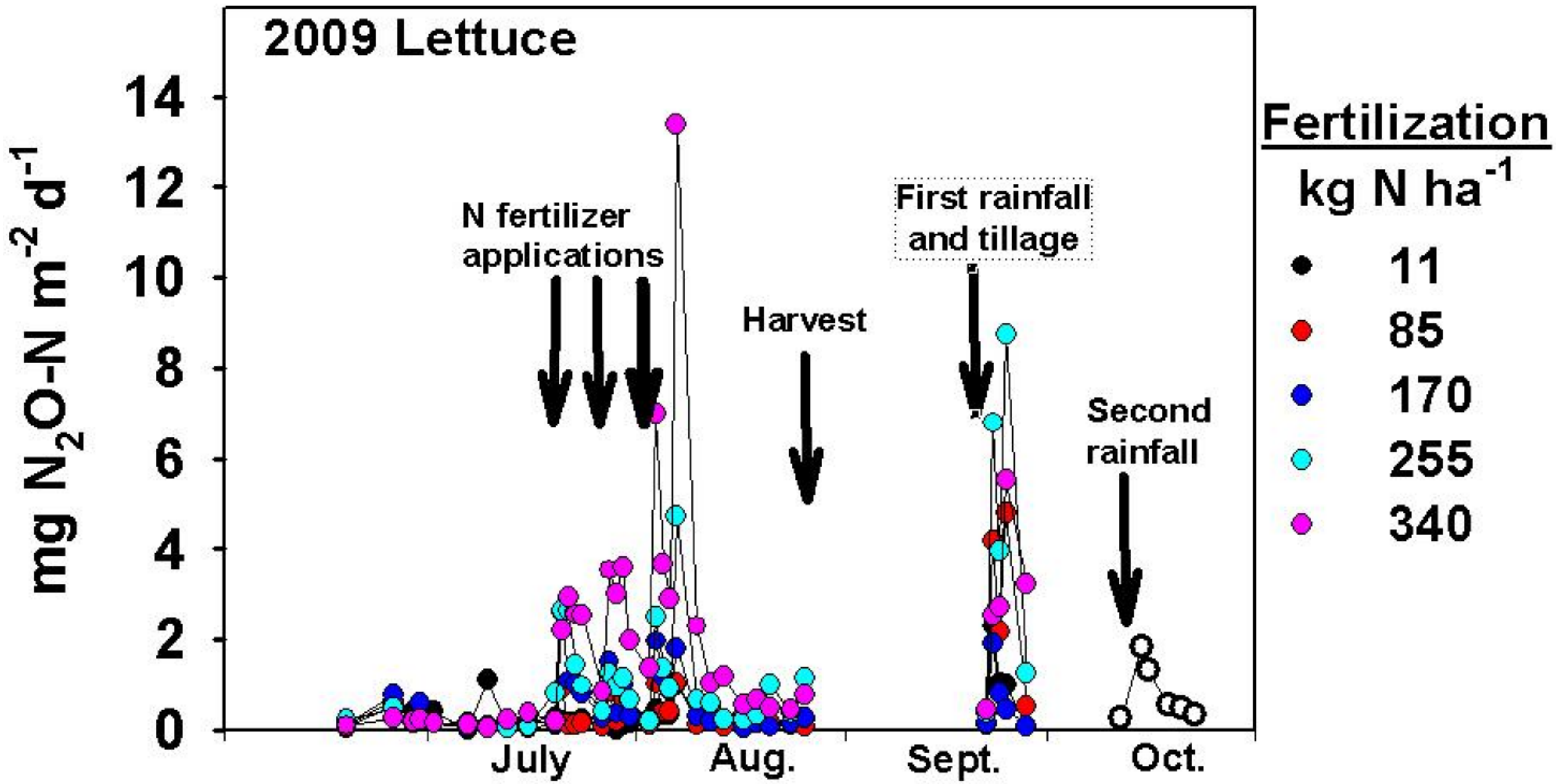
N_2O emissions are event based



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Tomato

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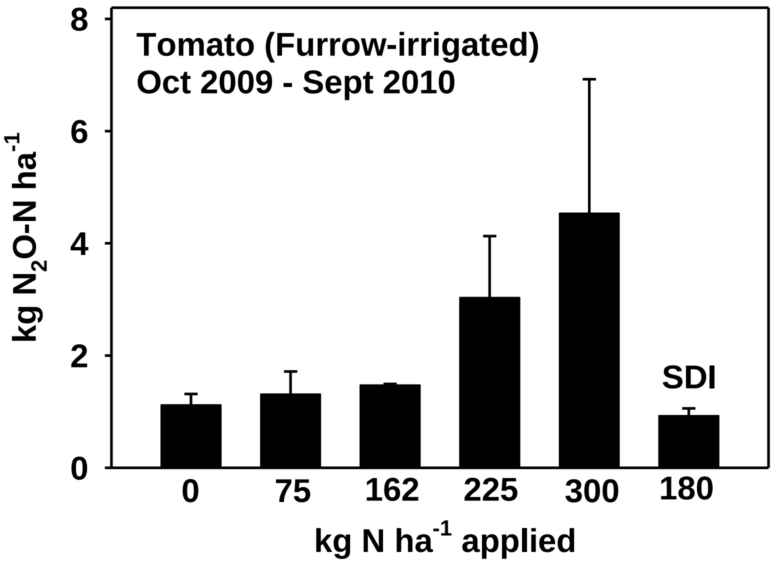
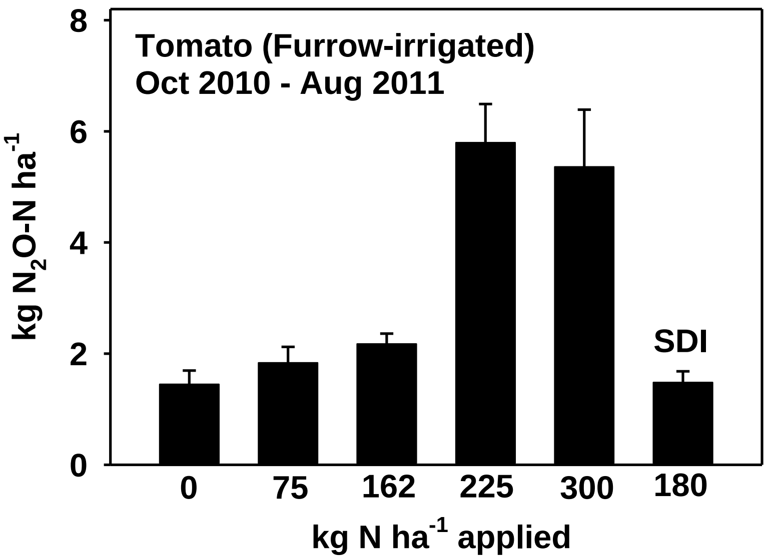
Processing Tomatoes: Annual N_2O Emissions Fertilizer Rate & Irrigation Effects





- Crop N off-take: 150 to 230 kg N ha^{-1}
- Maximum yield at about 162 kg N ha^{-1}

SDI=Subsurface drip

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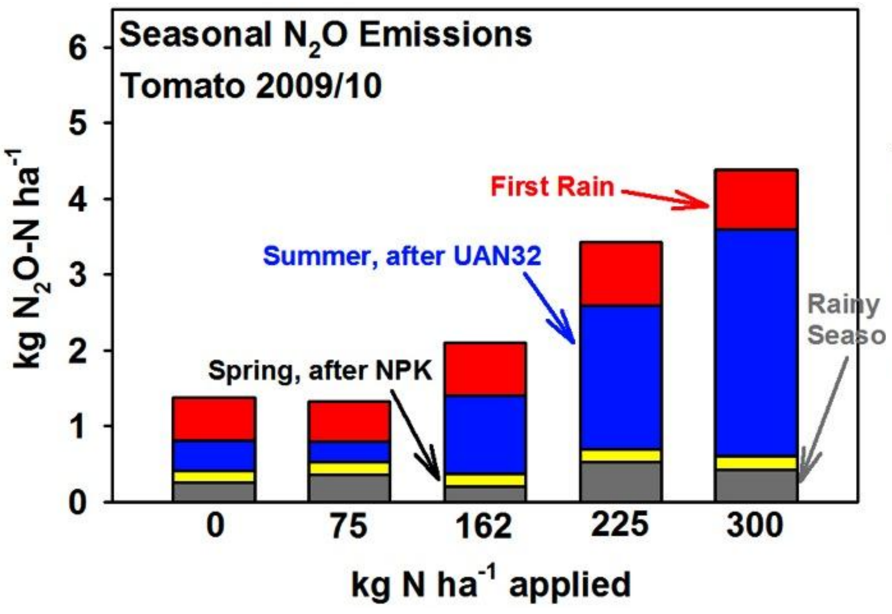
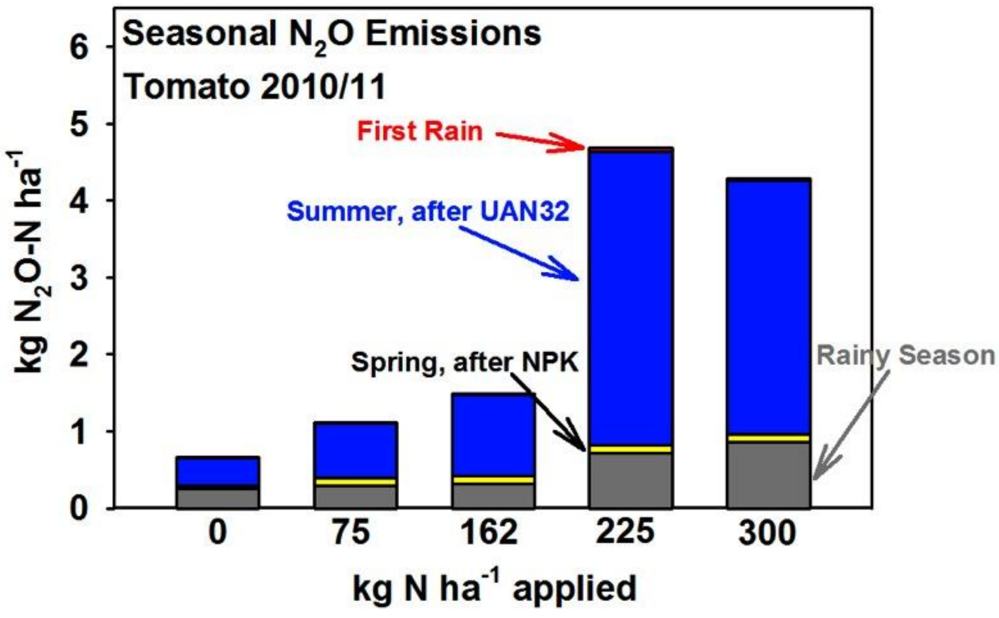
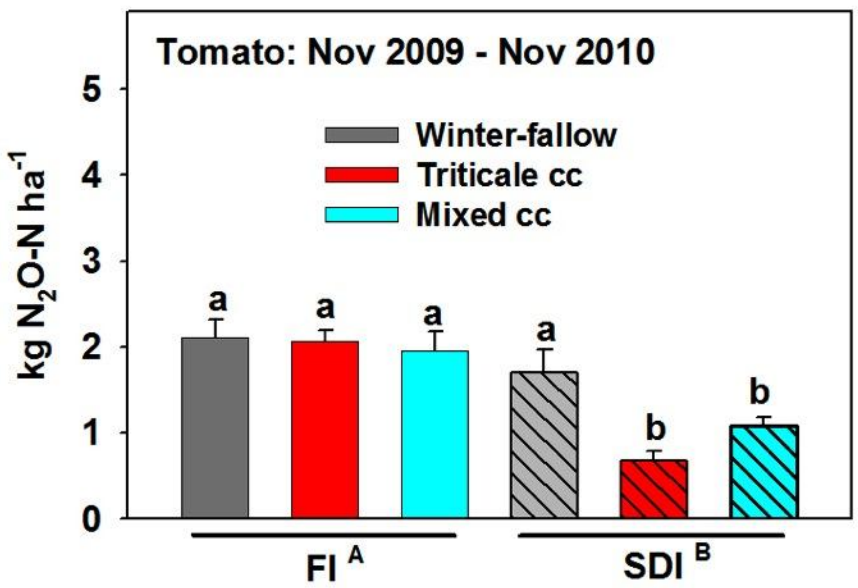
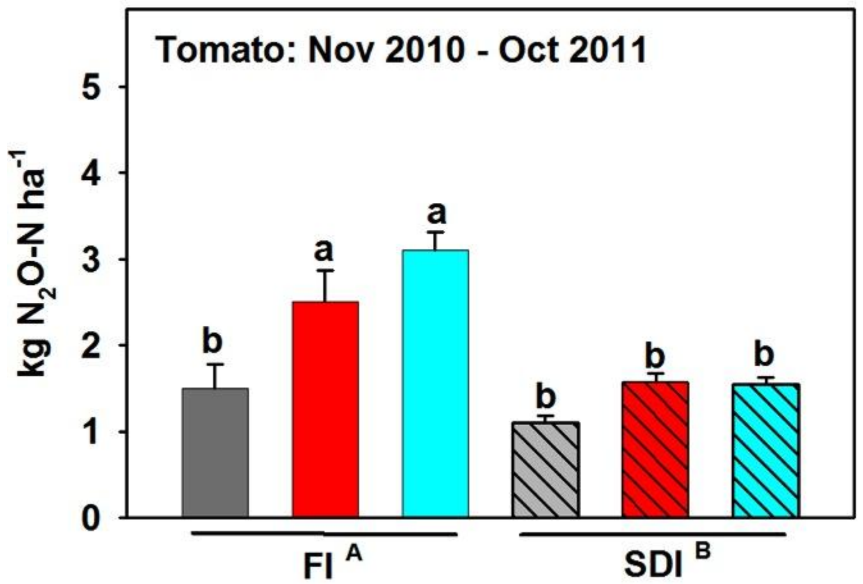
Timing of N_2O emission from different fertilizer events in the N rate trails Tomato





Annual N_2O Emissions in Tomato as a function of cover crops and irrigation practice





162 kg N ha^{-1} 179 kg N ha^{-1}

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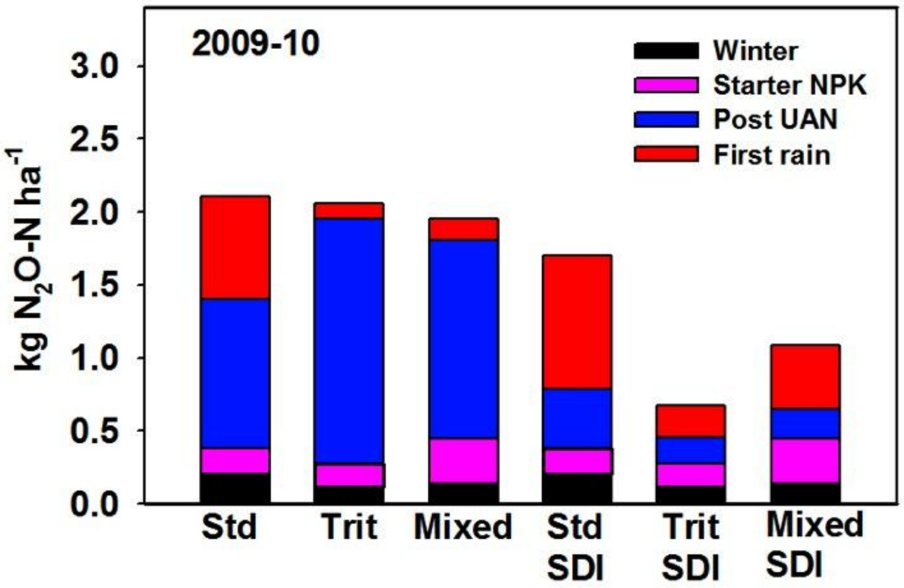
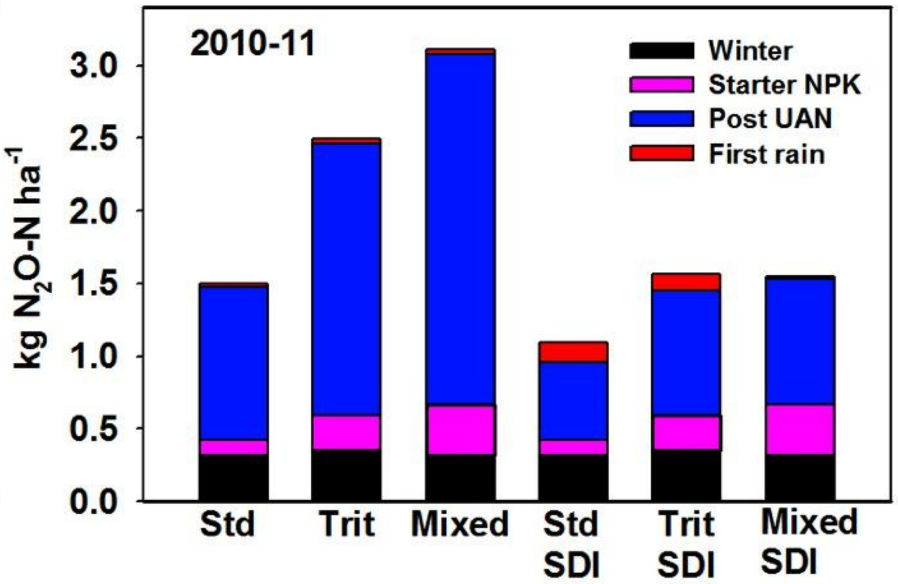
Seasonal Distribution of N_2O Emissions: Effect of cover crops and irrigation practice





SDI=Subsurface drip irrigation
Std= No cover crop
Trit=Triticale
Mixed=Legume/grass

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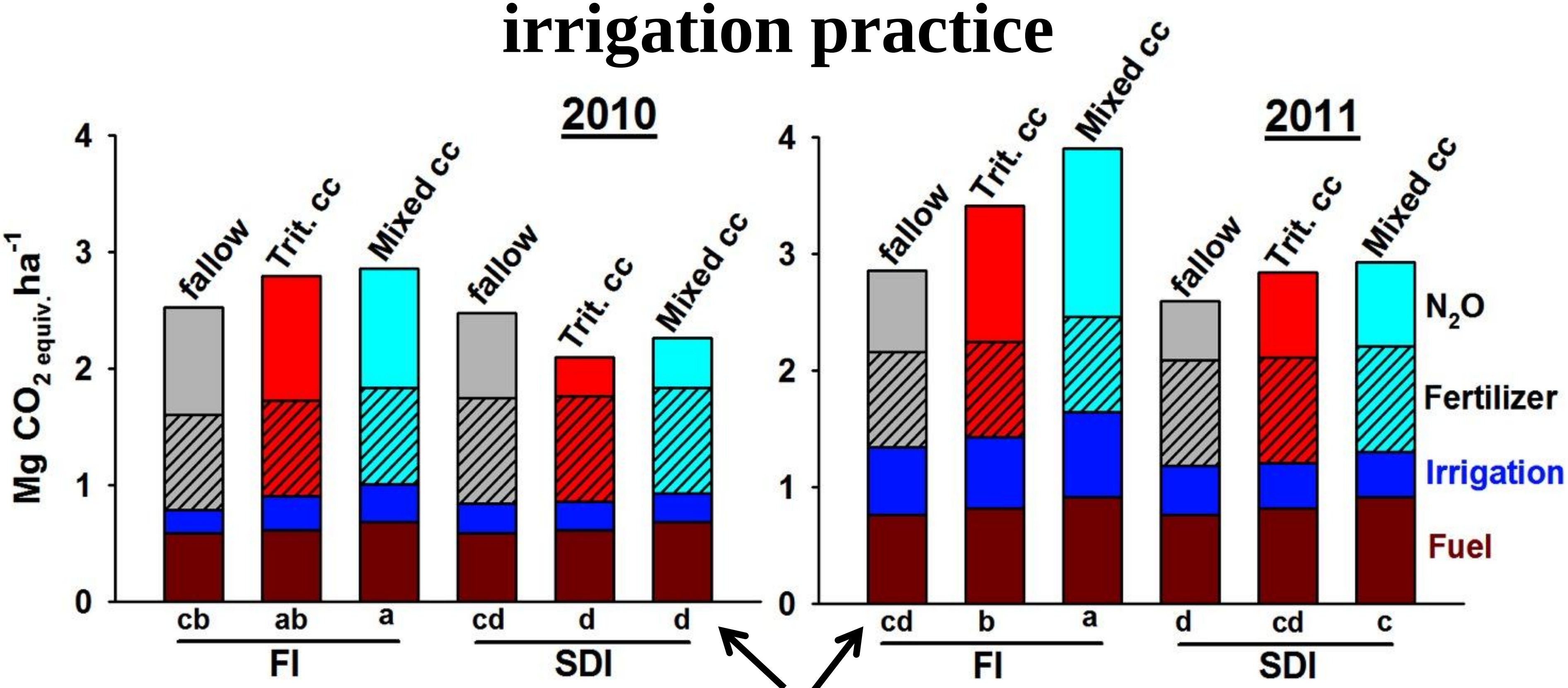
Sources of total greenhouse gas emissions in tomatoes as a function of cover crops and irrigation practice



Statistical significance

SDI=Subsurface drip irrigation
Fallow= No cover crop
Trit=Triticale
Mixed=Legume/grass

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Lettuce

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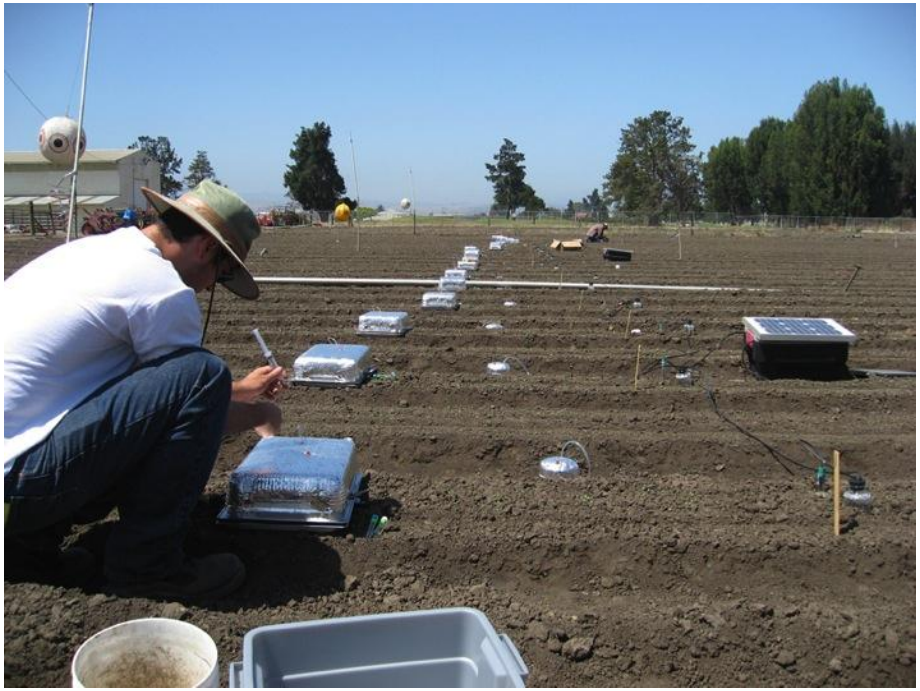
N_2O Flux in Response to N Fertilizer Rates at Experiment Site (Hartnell College)



- 5 N fertilizer rates (n=4)
- Subsurface drip irrigation
-2-year study:
    - One crop / year followed by year-round N_2O monitoring

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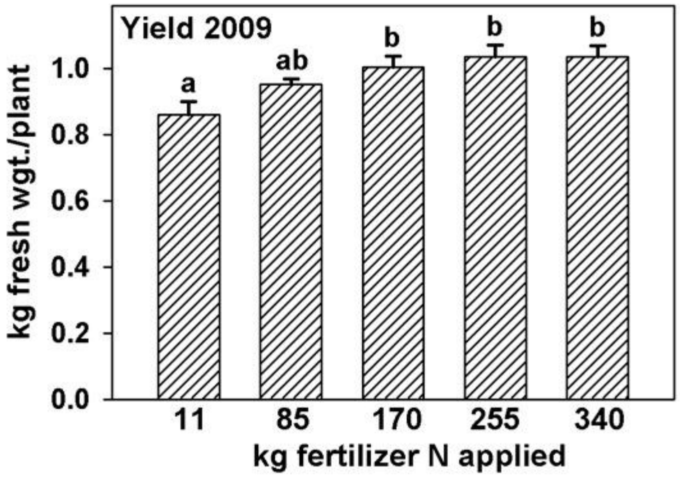
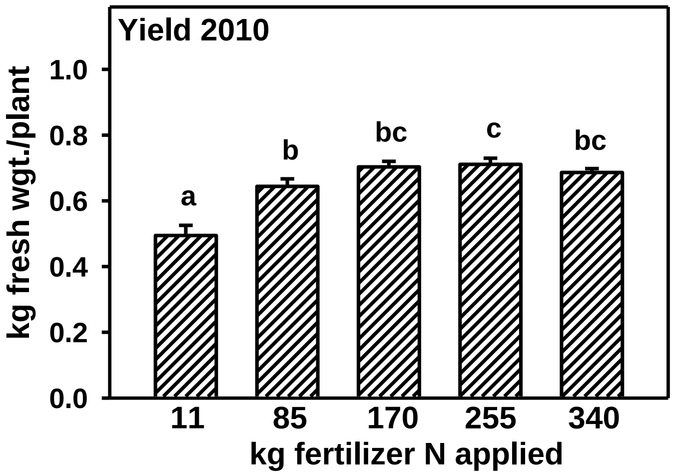
Lettuce Yields & Crop N Removal





Crop N off-take:

kgN/ha	
11	98.5
85	114.8
170	136.2
255	148.8
340	159.1

kgN/ha	
11	60.4
85	91.9
170	109.8
255	118.4
340	118.9

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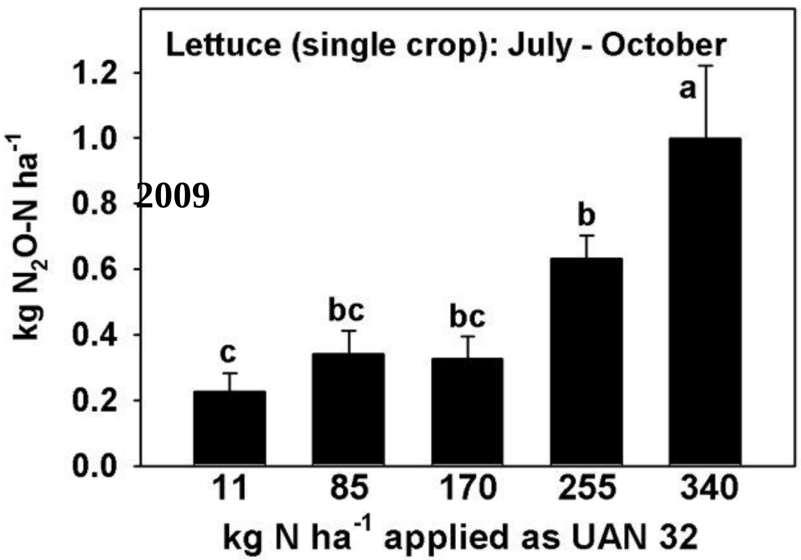
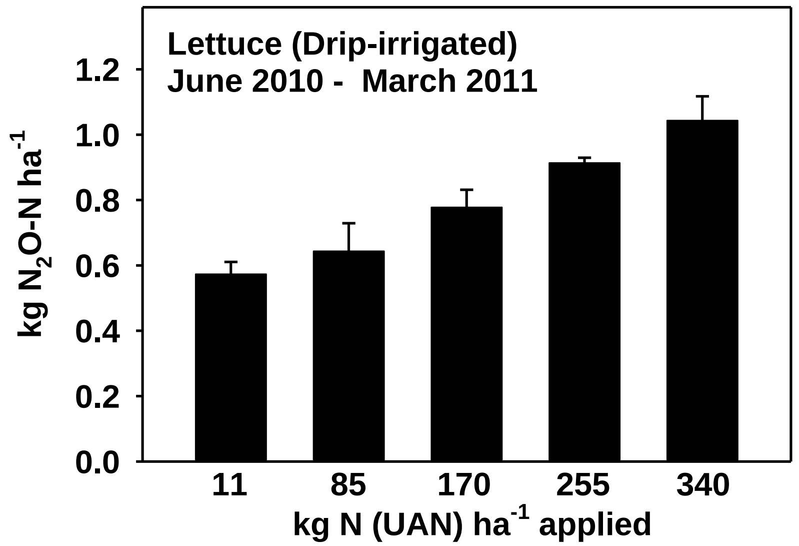
Lettuce: Annual N_2O Emissions



+ 0.36 kg N_2O-N ha^{-1} in winter



Off-season N_2O emissions (% of total annual):

62 52 53 37 27 59 4 41 32 37

Grower Field: 1.7 (0.4) kg N_2O-N ha^{-1} $crop^{-1}$

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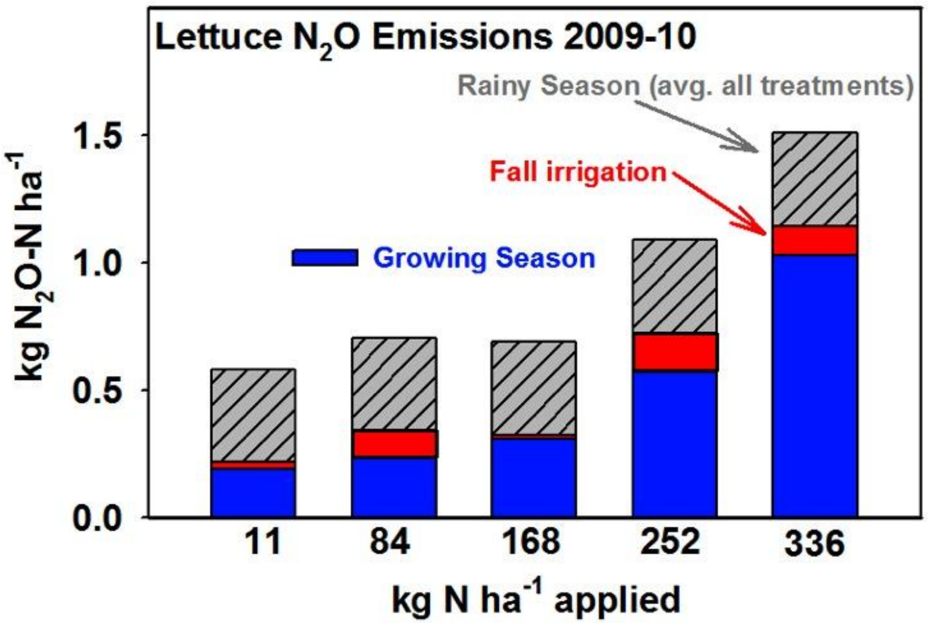
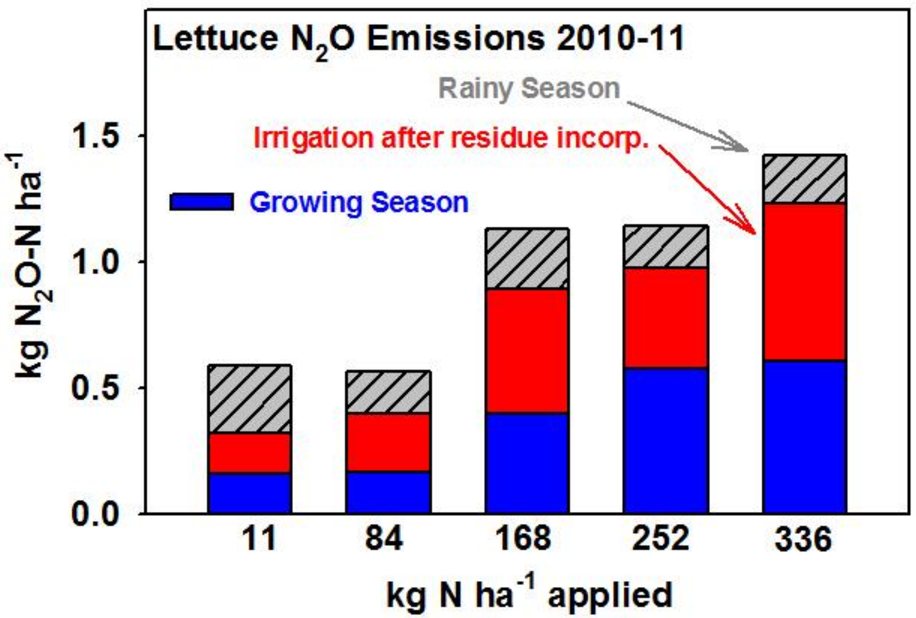
Lettuce: N_2O emission by season under surface-drip irrigation





N_2O emissions increased linearly with increasing N rates

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N_2O Emissions at Commercial Lettuce Farms

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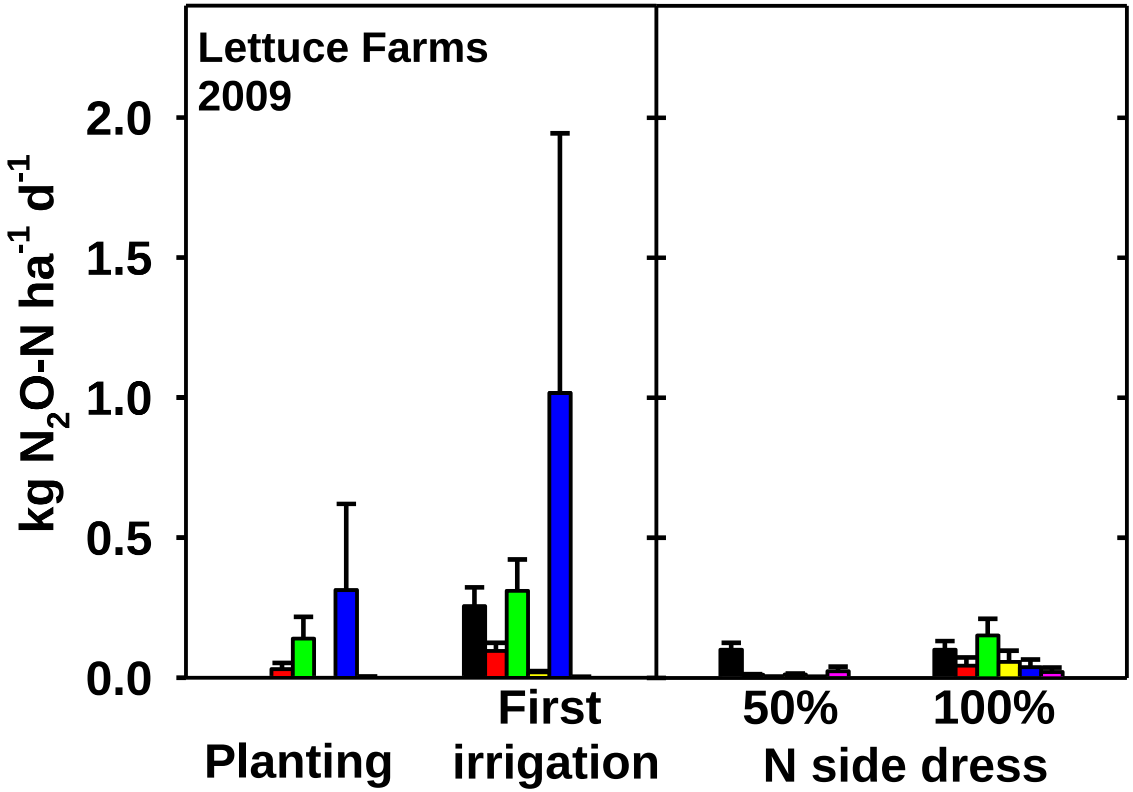
N_2O Fluxes across 6 farms using typical fertilization and irrigation practices



On-farm emission higher than experimental site but still low considering the amount of fertilizer N added

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On-farm Lettuce Yields

On-farm:

Yield of low N-rate as % of high N-rate yield

Farm A	**97**
Farm B	**92**
Farm C	**106**
Farm D	**101**
Farm E	**91**
Farm F	**104**
Mean	**98.5**

Maximum yield achieved with 50% of typical N application rate

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Annual Emission Factors for tomato and lettuce

Lettuce (one crop)				
kg N ha^{-1}	85	170	225	340
2009/10	.83	.41	.44	.40
2010/11	.76	.46	.41	.31
<u>Tomato</u>				
kg N ha^{-1}	75	162	225	300
2009/10	1.75	.91	1.35	1.51
2010/11	2.45	1.34	2.58	1.79

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Wheat

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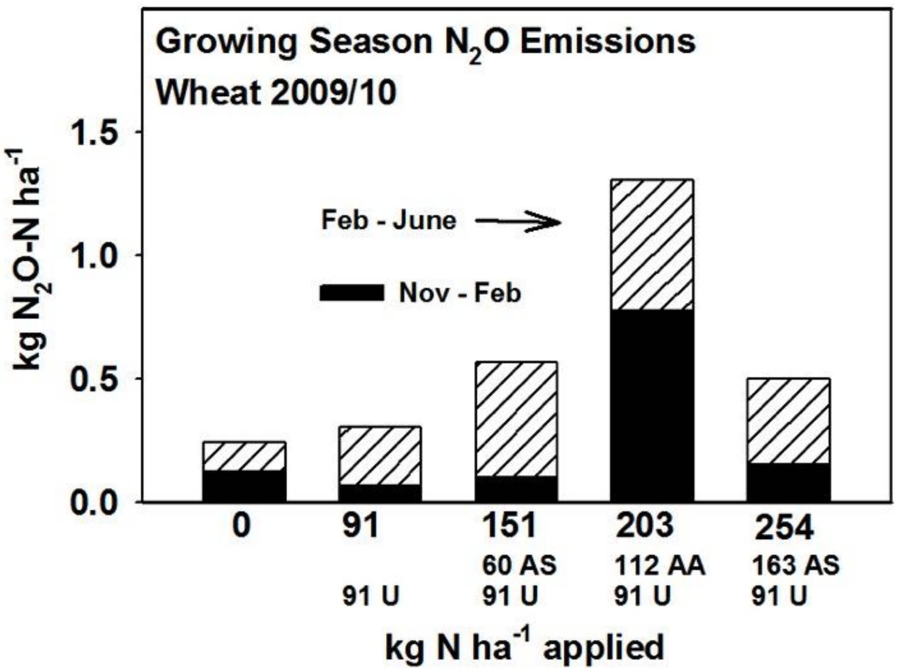
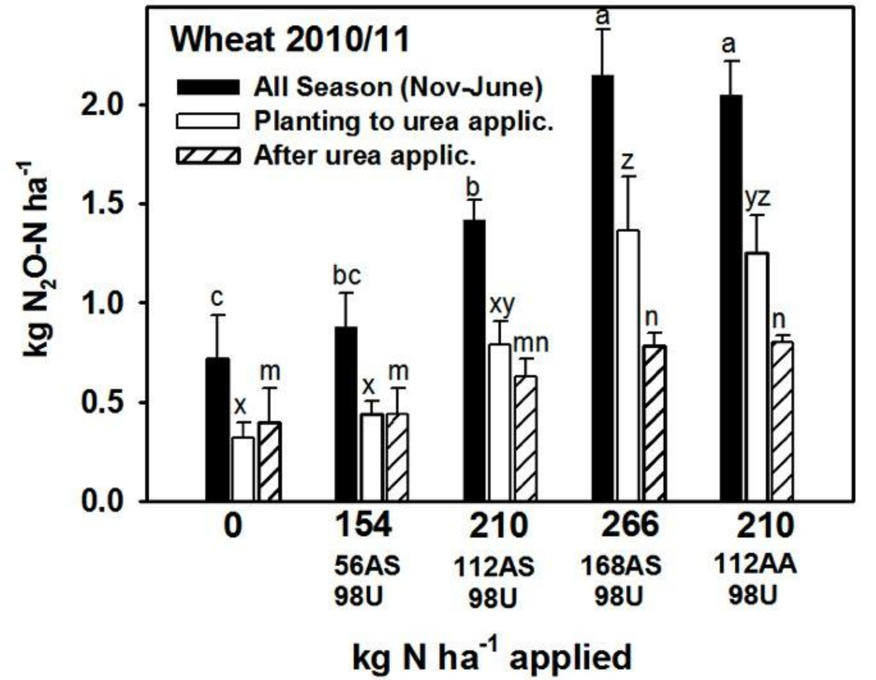
Wheat N_2O emissions under different fertilizer sources and N rates





Higher N_2O emissions with anhydrous ammonia than ammonium sulfate fertilizer

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Annual Emission Factors for Wheat

Wheat					
kg N ha^{-1}	91 AS&U	151 AS& U	205 AA&U		254 AS&U
2009/10	.35	.48	.63		.20
kg N ha^{-1}				205 AS&U	266 AS& U
2010/11		.35	.71	.48	.63

Alfalfa

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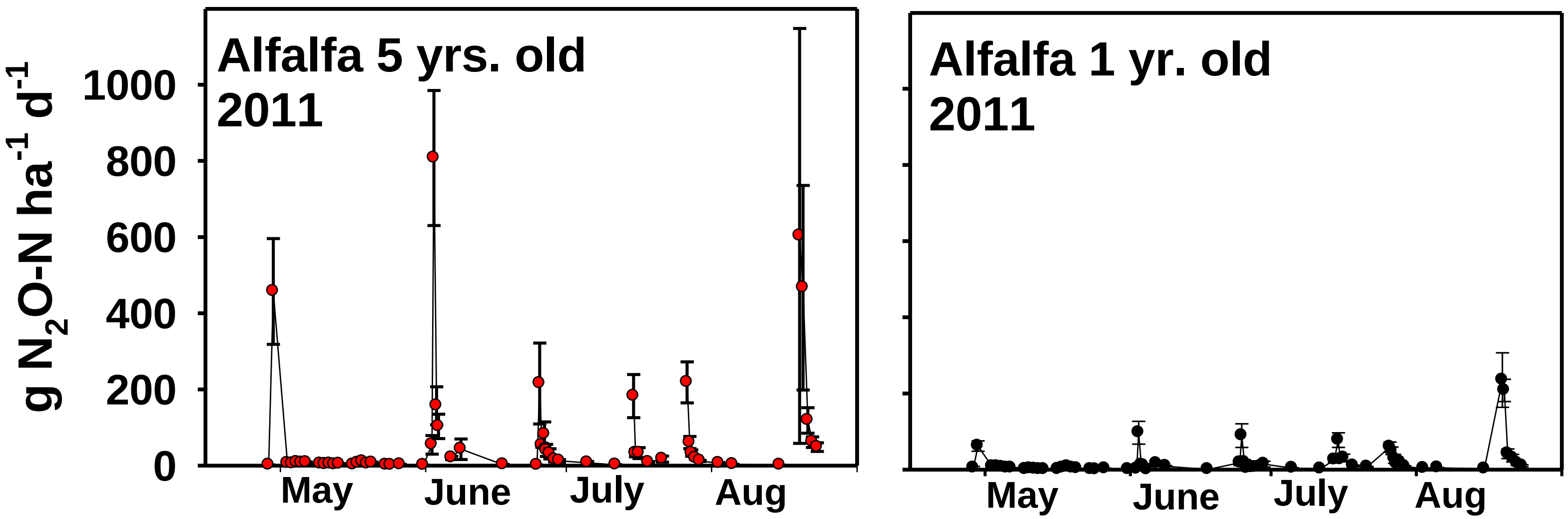
Alfalfa Systems N_2O Emissions



<u>**Annual emissions (kg N_2O-N ha^{-1}):**</u>

	Alfalfa 5 yrs. old	Alfalfa 1 yr. old
	4.42 (0.76)	**2.46 (0.33)**
off-season:	**9.4 (2.1)%**	**11.8 (3.2)%**
Crop N off-take:	**500-600 kg N ha^{-1}**	

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Wheat after Alfalfa

N application (kg N ha^{-1})	Grain N content (%)	Crop N removal (kg N ha^{-1})
0	1.6 b	147 c
154	1.9 a	194 b
210 (AS+U)	2.1 a	202 ab
266	2.1 a	220 ab
210 (AA+U)	2.1 a	233 a
ANOVA	P<0.05	P<0.05

- No yield response to different N rates
- Grain N content not different among N application treatments
- Apparent crop N removal close to 100%
- N credit due to the preceding alfalfa crop

Measuring Greenhouse Gas Flux from Green Compost Windrows

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Objective

- Measure greenhouse gas (GHG) flux from compost windrows
  - Methane
  - Nitrous oxide
- Use Chamber and Eddy Current techniques
- Laboratory incubations to characterize the effect of compost on N_2O emission on a range of agricultural soils
- Determine effect of field application of compost on N_2O emissions

Comparison of chamber vs. eddy current methods

Eddy Current method

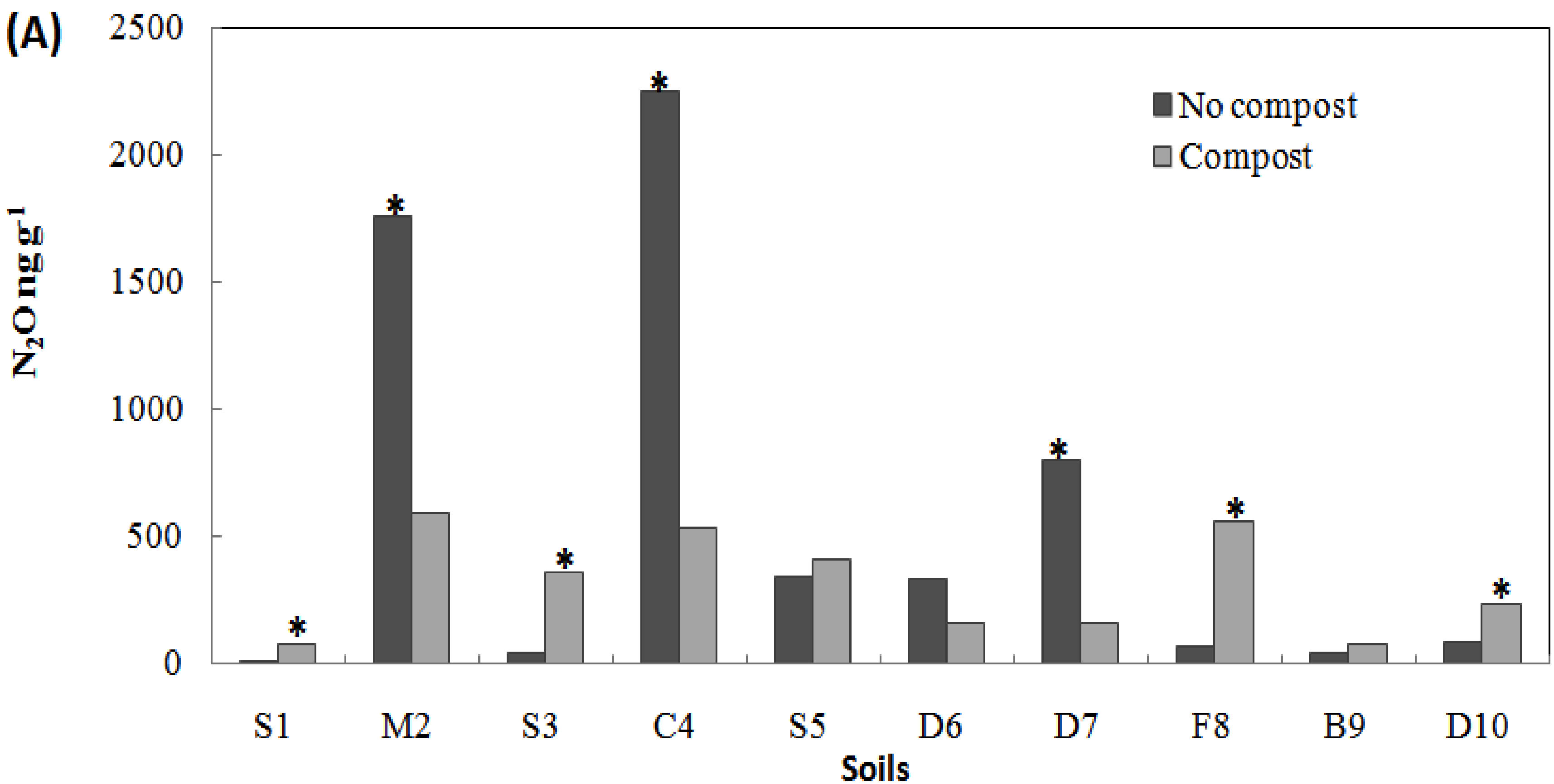
Period	*n*	CH_4 Flux [mg m^{-2} s^{-1}]		N_2O Flux [µg m^{-2} s^{-1}]		CO_2 Flux [mg m^{-2} s^{-1}]	
		Trapezoidal	Spline	Trapezoidal	Spline	Trapezoidal	Spline
A	45	0.315	0.528	2.57	6.58	23.6	46.1
B	133	0.134	0.240	-3.81	3.60	23.6	44.1
C	160	0.150	0.236	0.60	2.65	19.8	32.1
D	85	0.041	0.077	1.86	5.00	11.0	21.1
E	113	0.083	0.185	6.36	8.57	31.5	60.9
ALL	536	0.128	0.226	1.09	4.83	22.1	40.6

Chamber Method

Period	n (days)	CH_4 flux [mg m^{-2} s^{-1}]	NO_2 flux [µg m^{-2} s^{-1}]	CO_2 flux [mg m^{-2} s^{-1}]
A	1	0.146	1.364	24.601
B	8 (6)	0.218	3.332	37.519
C	1	0.471	1.299	71.712
D	2 (1)	0.046	3.181	39.714
E	2 (1)	0.037	6.012	36.389
ALL	14	0.181	3.408	39.191

- Methods compare well

Laboratory Incubation showing the influence of compost on N_2O emission from a range of agricultural soils with



- Generally little influence of compost on N_2O emission both under lab and field conditions

Summary & Conclusions

- N_2O emissions generally increase with increasing N fertilizer additions
- Emission factors are crop specific (no general value)
- Subsurface drip reduces N_2O emission compared to furrow irrigation
- Subsurface drip significantly reduces the cover crop effect during the growing season
- The carbon equivalents representing N_2O emissions from soil N and fertilizer N application is less than 30 to 50% of total farming fuel requirements and fertilizer N production
- Understanding N_2O production pathways will likely provide better insight into practices to reduce emission

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Future and Ongoing Studies

- ASSESSMENT OF BASLINE NITROUS OXIDE EMISSIONS IN CA DAIRY SYSTEMS (Ongoing)
- DETERMINING NO_X EMISSIONS FROM SOIL IN CA CROPPING SYSTEMS TO IMPROVE OZONE MODELING (Ongoing)
- Determine agronomic practices to reduce GHG emission (Ongoing)
- Mechanistic studies on pathways for N_2O production

Acknowledgements

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